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A NORDIC INTERCOMPARISON OF DETECTOR SYSTEMS FOR BACKGROUND RADIATION MONITORING

Lars Bøtter-Jensen and Sven Poul Nielsen

Abstract. A Nordic meeting sponsored by the Nordic Liaison Committee for Atomic Energy, was held at Risø 2-4 June 1980 with the aim of intercomparing detector systems for background radiation monitoring.

Several Nordic Laboratories participated in the intercalibration programme with different types of instruments and detectors. Ionization chambers appeared to yield the most reliable results but in general large variations of detector responses were found when the instruments were exposed identically. This demonstrates the need for intercomparison programmes and for establishing standardized calibration procedures.

(continue on next page)

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The present paper gives a description of the programme and presents the results for the assessment of background radiation monitoring with different sensitive doserate meters and integrating Tl dosimeters.

INIS descriptors: BACKGROUND RADIATION; CALIBRATION; CALIBRATION STANDARDS; COMPARITIVE EVALUATIONS; COSMIC RADIATION; ENVIRONMENT; EXPOSURE RATEMETERS; GEIGER-MUELLER COUNTERS; IONIZATION CHAMBERS; LI-DRIFTED GE DETECTORS; NAI DETECTORS; PLASRIC SCINTILLATION COUNTER; RADIATION DOSES; RADIATION MONITORING; THERMOLUMINESCENT DOSEMETERS.

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CONTENTS

1. INTRODUCTION

Presently, there is an increasing interest in the effects on humans of ionizing radiation from natural as well as from man-made sources. A discussion of the consequences on man due to our radioactive environment should therefore be based upon knowledge of the natural background radiation level.

The irradiation of members of the public from artificial sources is subject to control, and an essential part of this control is also the measurement of the environmental dose rate.

Detectors with ultra-high sensitivity and stability are demanded to obtain reliable long-term measurements of the fluctuating radiation levels and to differentiate between the natural background radiation and small superimposed artificial contributions. Furthermore, the composition of the background radiation is complex, complicating the interpretation of measurement results due to varying energy responses of different detectors.

Environmental radiation is widely measured with sensitive dose rate meters such as high pressure ionization chambers and scintillation and GM counters. The ICRP limit on the exposure of members of the public suggests that such instruments should be capable of measuring exposure rates from 1 to 100 μR/h with reasonable accuracy.

A common and widely experienced device for environmental measurements is the passive integrating solid state thermoluminescence dosimeter (TLD). These dosimeters have high sensitivity, a wide dynamic response, small size and for some phosphors an excellent energy response.

One of the most important factors in connection with low-exposure measurements is the calibration and standardization of the applied detectors. This is of special importance, when results are reported from one country to the other.

In order to carry out a measuring programme, to discuss the calibration procedures applied, and to see what types of instruments are used in the Scandinavian countries we took at Risø the initiative to arrange a Nordic intercalibration meeting.

The Nordic Liaison Committee for Atomic Energy (Nordisk Kontaktorgan for Atomenergispørgsmål) granted a sum of money to cover the travel expenses in connection with a Nordic intercalibration meeting which was held at Risø 2-4 June 1980 with 22 participants from Finland (2), Norway (3), Sweden (9) and Denmark (8). See participant list on page 31.

2. MEASURING PROGRAMME

The measuring programme of the meeting was divided into 4 parts.

1) Measurements of the natural exposure levels of indoor-environments.
2) Measurements of the background radiation as well as the radiation from low-active certified calibration sources in different geometries on a plane field site.
3) Measurements of background radiation on the open sea (fiord) in order to determine the cosmic component.
4) Irradiation of thermoluminescence dosimeters (TLD's) with small exposures for the assessment of TL dosimetry in connection with environmental monitoring.

Measurements of exposure rate levels of indoor environments are of special importance due to the increasing interest in the radiation exposure of man from building materials. One location for the indoor measurements was an ordinary cellar room with concrete walls representing a typical indoor exposure level. Another was a whole-body counter room where the high-energetic part of the cosmic component is dominating. The latter measurements served both as a linearity control of dose rate meters at ultra-low radiation levels and for checking the detector responses for high-energetic particles.

The open field measurements were carried out 1) to evaluate a typical natural background radiation level covering the terrestrial contribution from fall-out and natural radionuclides in addition to the cosmic component and 2) in the presence of the natural background to measure the radiation from point sources placed 1 meter above the ground level at different distances. The gamma radiation from certified ^{226}Ra and ^{137}Cs sources was used to verify the different detector responses. Fig. 2.1 shows a photograph of the experimental set-up at the field site.

Fig. 2.1. Experimental set-up at the field site.

In order to determine the response from the cosmic radiation, measurements were made onboard a ship on the nearby Roskilde Fiord, where the shielding effect of the water excludes the terrestrial component. An old steamboat using coal was hired for the occasion.

The last part of the intercomparison programme dealt with thermoluminescence dosimetry (TLD) and was carried out mainly to test accuracies and dose evaluation procedures for the different TLD systems. TL dosimeters provided by the participants were given low ^{137}Cs and ^{60}Co exposures in the Risø irradiation facilities, which had been intercalibrated with Nordic standards, using secondary standard ionization chambers to accuracies within 1%. The exposures, which were unknown to the participants, were chosen to be comparable to typical environmental exposures obtainable over 3 to 6 months. After the return to their respective laboratories the participants evaluated the TL-exposures and reported the results to Risø.

3. DETECTORS

The measuring results were obtained from 5 high-pressure ionization chambers, 5 NaI scintillation counters, 8 plastic scintillation counters, 5 Geiger Müller counters, 3 Ge(Li) detectors and 10 sets of TL dosimeter systems.

Four of the ionization chambers were commercially available types with either tape deck or digital integrator. The fifth ionization chamber was a Swedish home-made type with integrator facility. The scintillation counters were based on either plastic or NaI detectors with analog reading and some with an additional digital integrator.

GM counters were either small integrating pocket devices with digital display or ordinary count rate meters.
The Ge(Li) spectrometer systems were commercially available detectors connected to multichannel analysers.
The instruments and TL dosimeter systems are listed in Table 3.1 and Table 3.2 respectively.

Table 3.1. Code numbers for the instruments used in connection with the intercomparison programme.

Instrument code No.	Detector	Manufacturer / type	
1	High pressure ionization chamber	Reuter & Stokes	RSS-111
2	" " " "	" "	RSG-42
3	" " " "	" "	RSS-111
4	" " " "	Home made	A8
5	" " " "	Reuter & Stokes	RSS-111
6	Plastic scintillator	Studsvik	2414 A
7	" "	"	"
8	" "	"	"
9	" "	"	"
10	" "	"	"
11	" "	"	"
12	Plastic scintillator /ZnS	Münchener apparatebau	MAB 604
13	" " "	" "	MAB 604.1
14	NaI scintillator	Scintrex	BGS-3
15	" "	"	BGS-4
16	" "	Techsnabexbort (USSR)	SRP-68-01
17	" "	Scintres	BGS-4
18	" " /spectrometer	Geometrics Exploranium	GR-410
19	GM counter	Mini Instruments	5.10
20	" "	XETEX	415A-B
21	" "	"	"
22	" "	Berthold	LB1200 int.det.
23	" "	"	" ext.det.

Table 3.2. **Code numbers for TL systems used in connection with the intercomparison programme.**

System No.	TL material/(manufacturer)
1	LiF (TLD 700, Harshaw)
2	LiF (TLD 100, Harshaw)
3	LiF (TLD 700, Harshaw)
4	LiF (TLD 700, Harshaw)
5	$Li_2B_4O_7$: Mn (Studsvik)
6	$CaSo_4$: Dy/teflon (Teledyne Isotopes)
7	LiF (TLD 700, Harshaw)
8	$Li_2B_4O_7$: Mn (Studsvik)/LiF (TLD 700, Harshaw)
9	$CaSo_4$: Dy/teflon (Teledyne Isotopes)
10	$CaSo_4$: Dy/teflon (Teledyne Isotopes)

4. DATA EVALUATION

The free field measurements with certified ^{137}Cs and ^{226}Ra sources were performed similar to a calibration procedure used at Risø for the past 4 years. The method is based on a free field set up with source and detector placed at the same height above the ground. The radiation components to be considered were the natural background, the primary beam from the source, the scattered component from the ground surface, and the build-up in the air. The air-attenuation of the primary beam was also considered. According to the Chilton and Huddleston formula for the differential dose albedo for gamma-rays on concrete (1), reliable albedo figures for different geometries were calculated. Albedo data for ^{137}Cs, ^{226}Ra and ^{60}Co sources are given in Fig. 4.1.

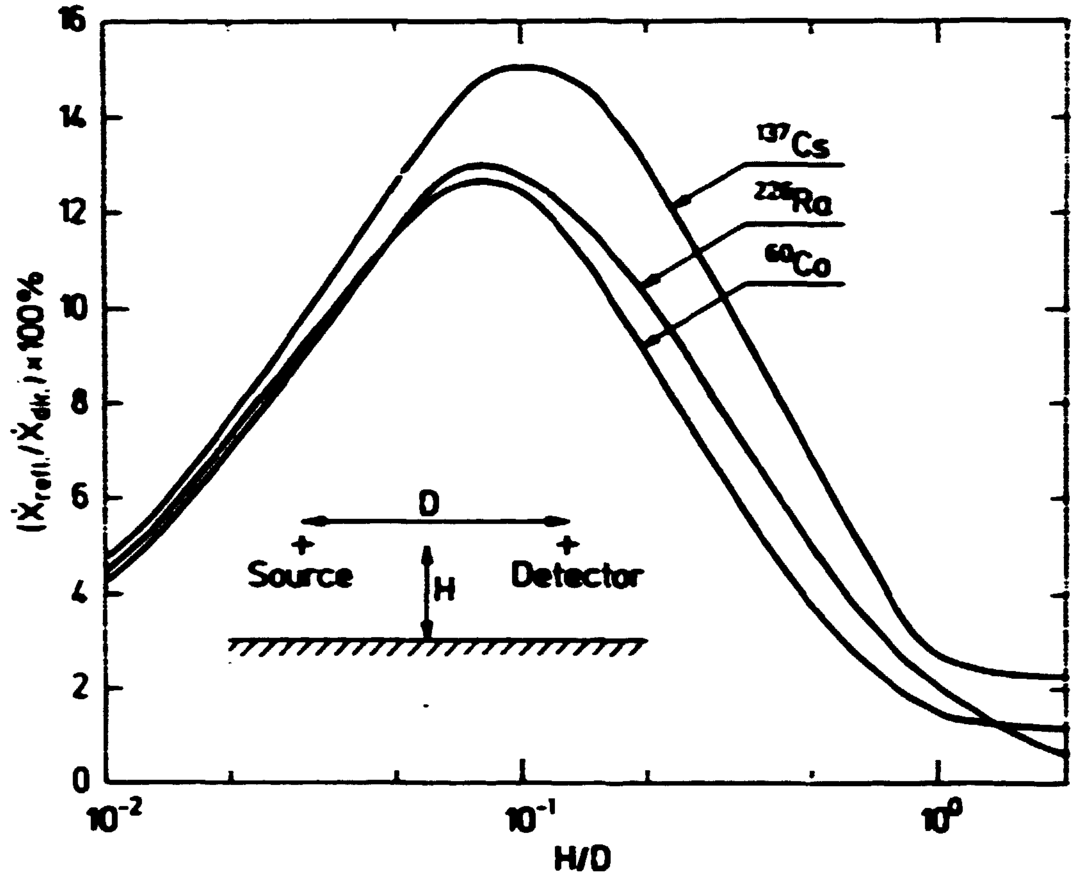

Fig. 4.1. Reflected exposure rate $\dot{X}$ refl. from a plane concrete surface in percent of directly exposure rate $\dot{X}$ dir. as a function of height and distance for ^{137}Cs, ^{226}Ra and ^{60}Co gamma point sources.

Previous calibration experiments and calculations have shown that the dose albedo for the ground surface is significant whereas the sum of the attenuation and the build-up in air is negligible. Therefore only the scattered gamma-ray components from the ground were considered in the present experiments. The calculated albedo correction figures for ^{137}Cs and ^{226}Ra sources at 1 m height and the applied distances are given in Table 4.1. The certified sources used were ^{226}Ra, 0.949 mCi ± 0.5% and ^{137}Cs, 4 mCi ± 5%, produced by Amersham. The ^{226}Ra exposure rates were calculated using an exposure rate constant of 0.825 $Rm^2\ h^{-1}\ g^{-1}$ and the ^{137}Cs data were calculated from a certified exposure rate specified at a distance of 1 m.

Table 4.1. Calculated albedo correction figures and estimated exposure rates for ^{137}Cs and ^{226}Ra calibration sources (open field set-up) at a height of 1 m above ground and at different distances.

Source	Distance (m)	Albedo (%)	Calculated exposure rate (μR/h)
^{137}Cs	3	9.7	165.5
	5	13.0	61.4
	10	15.0	15.6
^{226}Ra	3	7.3	93.4
	5	10.3	34.5
	10	12.8	8.8

The statistical analyses of the data were made with the STATDATA computer program (2). The following levels were used in the significance tests: Probably significant ($P \geq 95\%$), significant ($P \geq 99\%$) and highly significant ($P \geq 99.9\%$).

5. RESULTS AND DISCUSSION

5.1. Measurements of background radiation.

The results from the measurements of background radiation with ionization chambers, plastic scintillators, NaI scintillators and GM counters are shown in the Tables 5.1.1 - 5.1.4 and in the Figs. 5.1.1 - 5.1.4. The detector numbers refer to the description given in Table 3.1.

The GM counter results show large variations mainly due to uncompensated dark currents. The results from the plastic- and the

NaI scintillators also show variations, which are mainly due to varying responses to the secundary cosmic radiation, see Fig. 5.1.1. Table 5.1.5 and Fig 5.1.5 show the results from the open field site, normalized by subtracting the readings from Roskilde Fiord. These results thus represent the terrestrial γ-component at the open field site and it is noted that a reasonable agreement between the four types of detectors is obtained.

A Ge(Li) spectrometer was used on the Roskilde Fiord for the determination of the γ-background. The recorded γ-spectrum showed the presence of ^{137}Cs, ^{40}K and the γ-emitting daughters of ^{226}Ra and ^{232}Th. It was further estimated from the evaluated spectrum that the total γ-background, originating from the fall-out contamination of the deck and from 3.5 tons coal carried to run the steam engine contributed only about 0.3 μR h^{-1}, which was considered negligible.

Measurements were made at the open field site with the three Ge(Li) spectrometer systems and the NaI spectrometer (detector no. 18). Table 5.1.6 shows the unattenuated γ-flux densities recorded with the Ge(Li) detectors and Table 5.1.7 shows the estimated soil concentrations of the naturally occuring radionuclides.

Table 5.1.1. Ionization chamber results from measurements of background radiation (μR h^{-1}).

Location	Detector No. 1	2	3	4	5	Mean	1SD(%)
Shielded basement	1.7	2.1	1.8	0.5	2.0	1.6	40
Basement	8.5	7.8	7.4	7.0	9.1	8.0	11
Open field	8.0	7.9	8.0	6.0	8.0	7.6	12
Roskilde Fiord	3.8	4.0	3.4	3.0	4.0	3.6	12

Table 5.1.2. Plastic scintillator results from measurements of background radiation (μR h^{-1}).

Location	Detector No. 6	7	8	9	10	11	12	13	Mean	1SD(%)
Shielded basement	2.0	1.6	1.4	1.5	1.2	1.2	1.8	0.9	1.5	25
Basement	8.0	9.5	8.0	8.0	7.5	9.0	9.5	5.9	8.2	15
Open field	11.0	8.0	8,0	6.5	6.5	7.5	8.5	5.1	7.6	23
Roskilde Fiord	2.5	2.5	2.7	2.5	1.9	2.5	3.5	2.0	2.5	19

Table 5.1.3. NaI (Tl) scintillator results from measurements of background radiation (μR h^{-1}).

Location	Detector No. 14	15	16	17	18	Mean	1SD(%)
Shielded basement	0.1	0.2	0.3	0.5	-	0.3	64
Basement	5.1	5.1	8.6	6.0	(4.9*)	6.2	27
Open field	4.6	4.3	7.5	6.0	(3.8*)	5.6	26
Roskilde Fiord	0.5	0.6	0.8	1.0	-	0.7	34

* Corrected for cosmic and inherent background.

Table 5.1.4. GM counter results from measurements of background radiation (μR h^{-1}).

Location	Detector No. 19	20	21	22	23	Mean	1SD(%)
Shielded basement	6.5	13.0	12.0	3.0	2.0	7.3	69
Basement	14.0	21.0	21.0	8.0	11.0	15.0	39
Open field	13.0	19.0	19.0	10.0	10.0	14.2	32
Roskilde Fiord	9.5	15.0	14.0	4.0	4.0	9.3	57

Table 5.1.5. Terrestrial exposure rates obtained by subtracting the Roskilde Fiord results from the open field results.

Detectors		$\mu R\ h^{-1}$	Mean	1SD(%)
	1	4.2		
	2	3.9		
Ionization chambers	3	4.6	3.9	15
	4	3.0		
	5	4.0		
	6	8.5		
	7	5.5		
	8	5.3		
Plastic scintillators	9	4.0	5.1	31
	10	4.6		
	11	5.0		
	12	5.0		
	13	3.1		
	14	4.2		
	15	3.8		
NaI (Tl) scintillators	16	6.7	4.7	27
	17	5.0		
	18	3.8		
	19	3.5		
	20	4.0		
GM counters	21	5.0	4.9	23
	22	6.0		
	23	6.0		

Table 5.1.6. Germanium detector results of unattenuated γ-flux from measurements of the background radiation in an open field (γ cm^{-2} s^{-1}).

Nuclide, γ-energy	Detector No. 1	2	3
^{226}Ra , 295 keV	0.015	0.010	0.008
" , 352 keV	0.026	0.023	0.027
" , 609 keV	0.054	0.040	0.046
" , 1120 keV	0.025	0.018	0.038
" , 1765 keV	0.028	0.027	0.027
^{232}Th , 338 keV	0.007	0.010	0.006
" , 583 keV	0.032	0.036	0.036
" , 911 keV	0.029	0.033	0.038
^{40}K , 1461 keV	0.396	0.400	0.390
^{137}Cs , 662 keV	0.068	0.063	-

Table 5.1.7. Gamma-spectrometer results of radionuclide concentrations in the soil from measurements in an open field (pCi g^{-1}).

Nuclide	Ge detector 1	Ge detector 2	Ge detector 3	NaI detector 18
^{226}Ra	0.53	0.40	0.52	0.54
^{232}Th	0.43	0.45	0.45	0.51
^{40}K	11	11	11	11

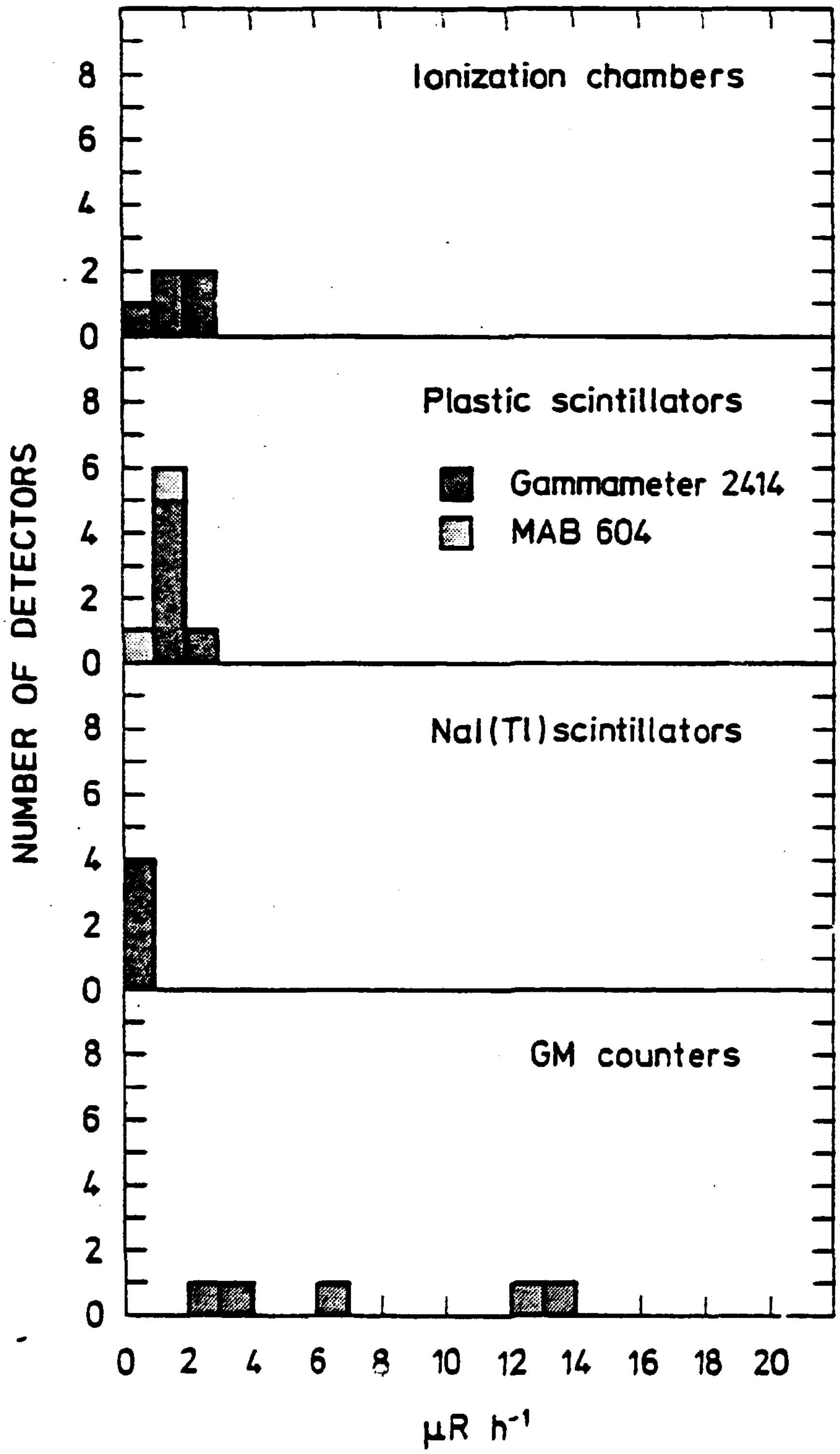

Fig. 5.1.1. Results from measurements in a shielded basement.

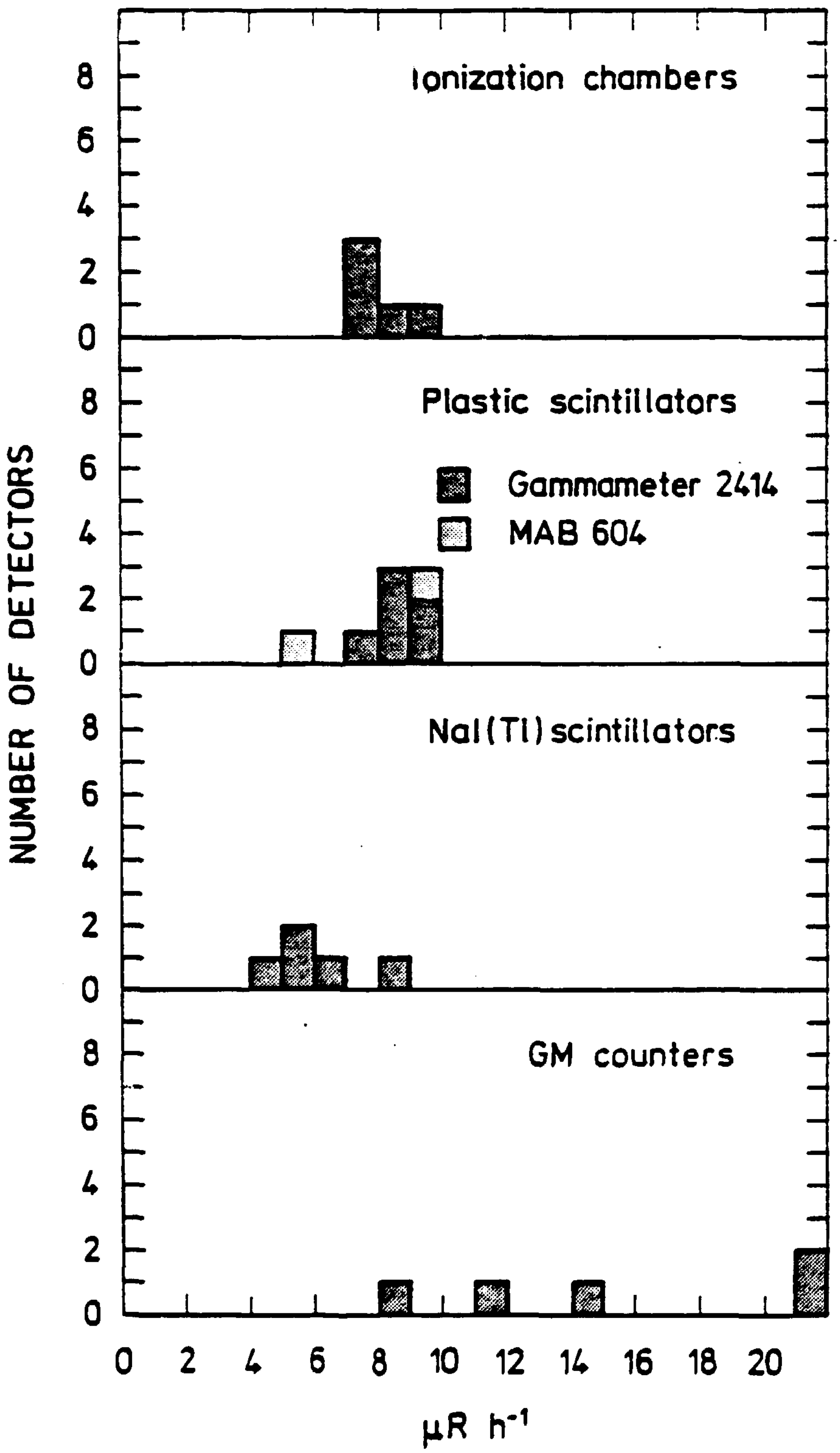

Fig. 5.1.2. Results from measurements in an ordinary basement.

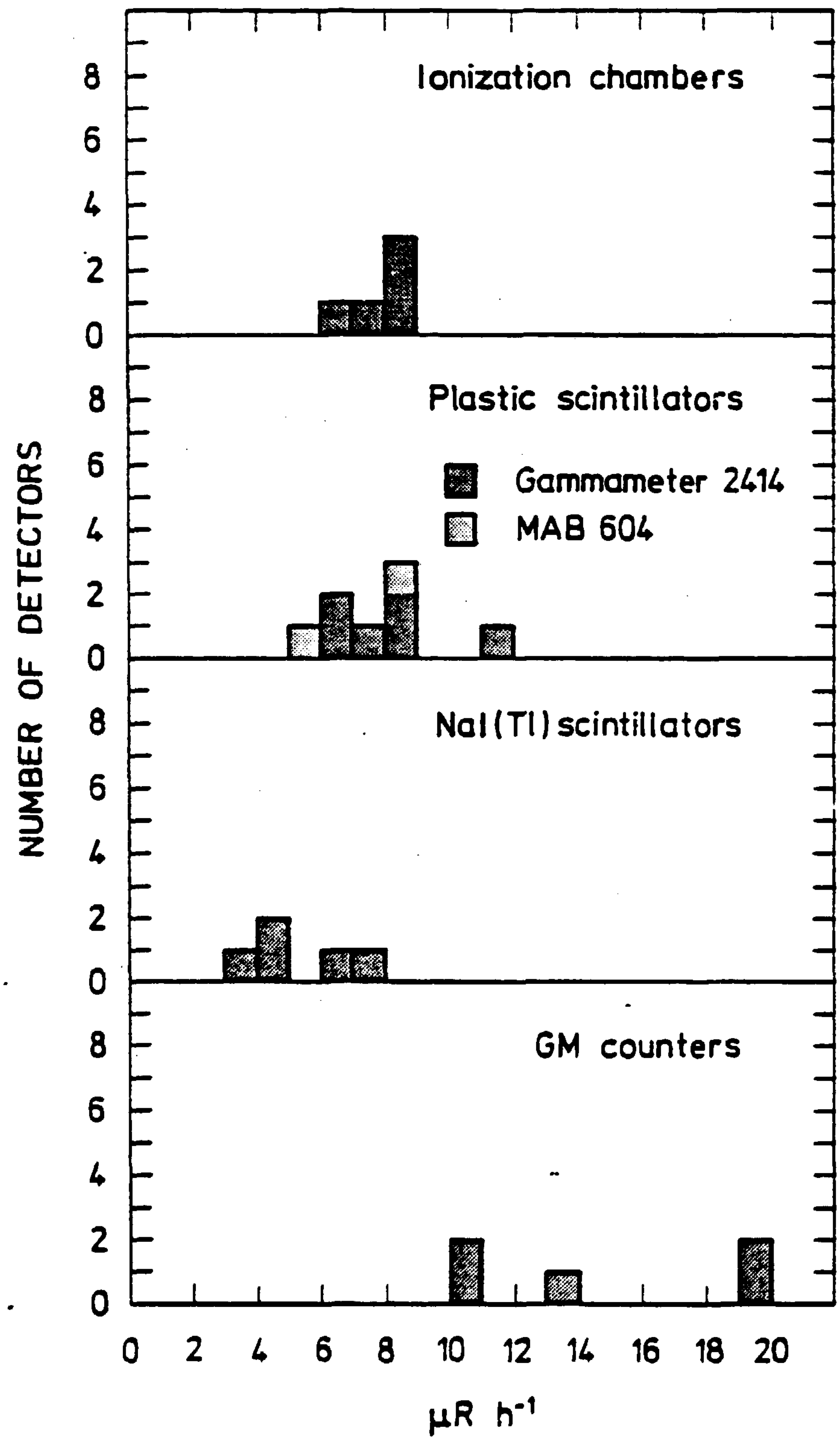

Fig. 5.1.3. Results from measurements at the open field.

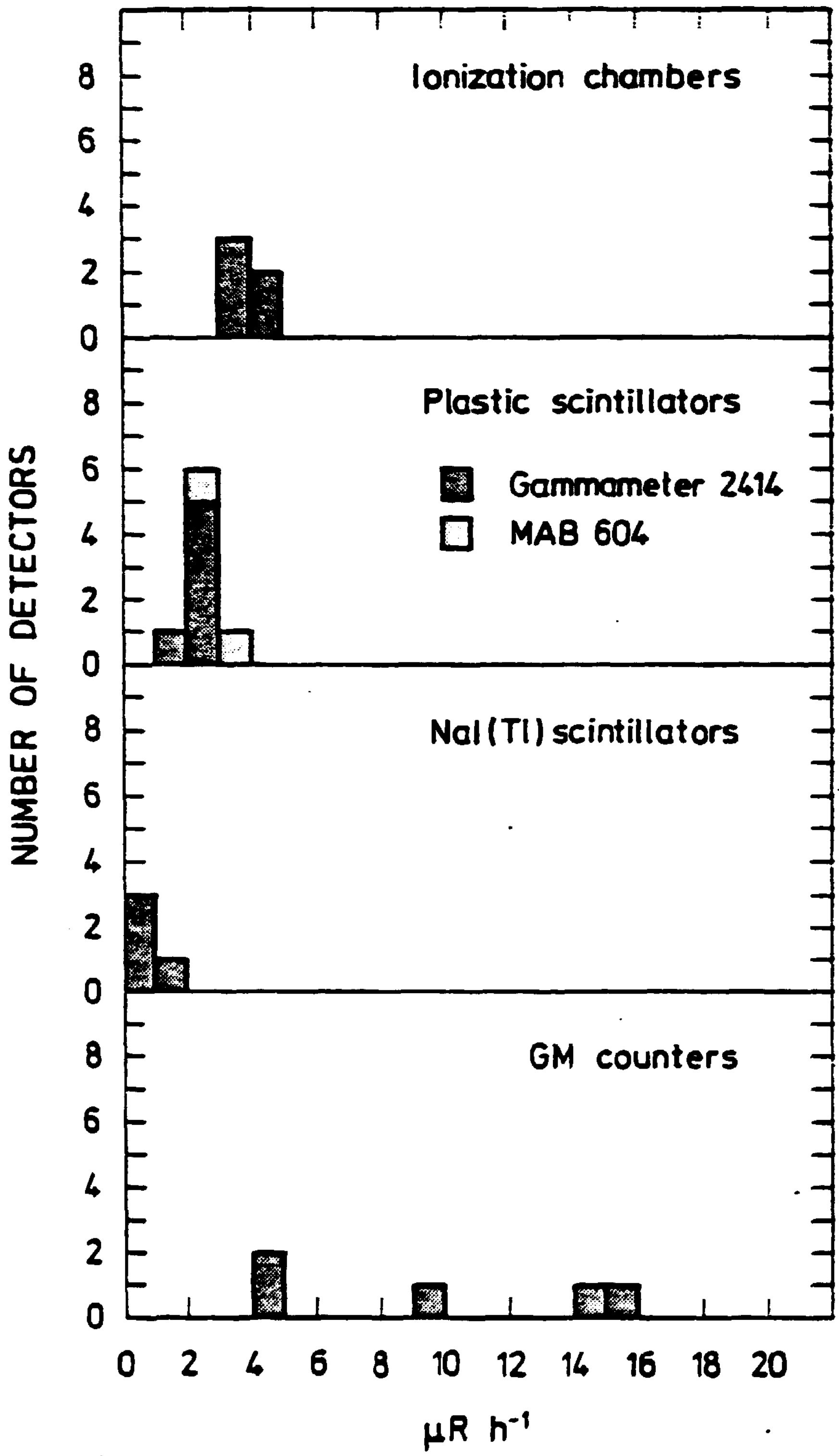

Fig. 5.1.4. Results from measurements on the Roskilde Fiord.

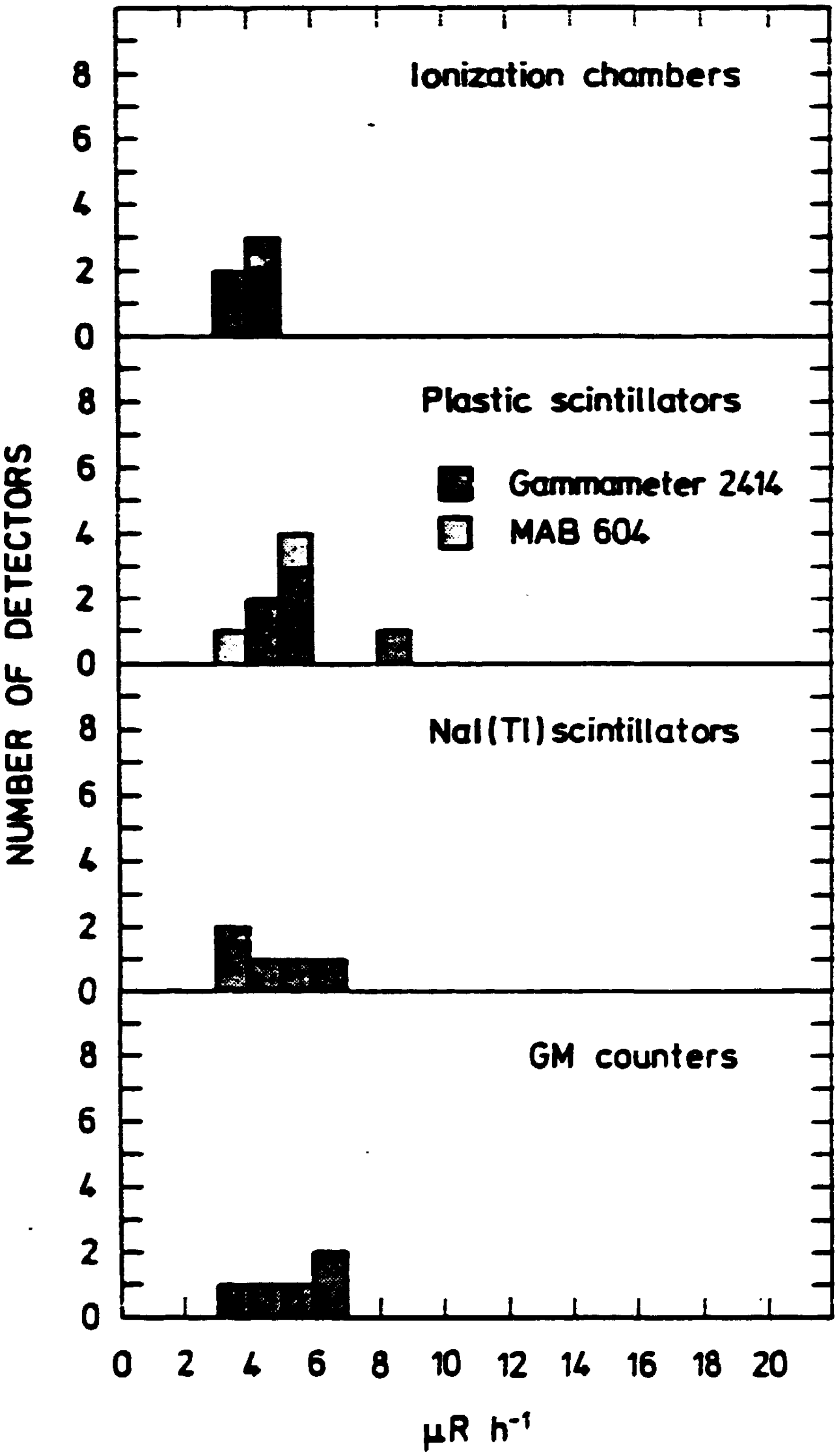

Fig. 5.1.5. Results from measurements of the terrestrial component at the open field site.

5.2. Measurements of calibration sources.

The results from the measurements of the ^{226}Ra and ^{137}Cs calibration sources with ionization chambers, plastic scintillators, NaI scintillators and GM counters are shown in the Tables 5.2.1 - 5.2.4. The natural background readings have been subtracted and the results adjusted slightly to correspond to the reference distances of 3, 5 and 10 m by using the inverse square law.

Table 5.2.1. Ionization chamber results from measurements of calibration sources ($\mu R\ h^{-1}$).

Source, distance	Detector No. 1	2	3	4	5	Mean	1SD(%)
^{226}Ra , 10 m	8.5	8.5	7.0	8.8	8.7	8.3	9
" , 5 m	34.1	34.1	29.8	33.7	33.9	33.1	6
" , 3 m	94.9	88.2	83.8	89.0	93.6	89.9	5
^{137}Cs , 10 m	15.5	15.0	13.0	13.6	14.9	14.4	7
" , 5 m	61.2	58.1	56.6	58.5	61.1	59.1	3
" , 3 m	163.5	151.6	151.7	154.0	164.3	157.0	4

Table 5.2.2. Plastic scintillators results from measurements of calibration sources ($\mu R\ h^{-1}$).

Source, distance	Detector No. 6	7	8	9	10	11	12	13	Mean	1SD(%)
^{226}Ra , 10 m	11.0	14.0	11.7	13.2	11.8	12.4	11.7	7.2	11.6	18
" , 5 m	55.0	52.0	49.5	41.9	40.0	48.7	45.6	29.8	45.3	18
" , 3 m	150.0	127.0	122.5	107.5	98.1	126.2	113.5	85.0	116.2	17
^{137}Cs , 10 m	27.0	24.0	23.9	23.0	18.1	23.4	24.2	14.0	22.2	19
" , 5 m	110.0	87.0	83.5	73.9	69.2	80.2	95.5	58.3	82.2	19
" , 3 m	270.0	202.0	204.1	192.8	192.8	222.5	239.5	167.4	211.4	15

Table 5.2.3. NaI (Tl) scintillator results from measurements of calibration sources (μR h^{-1}).

Source, distance	Detector No. 14	15	16	17	18	Mean	1SD(%)
^{226}Ra , 10 m	5.4	5.7	7.0	6.6	8.6	8.6	19
" , 5 m	23.5	23.6	31.5	28.2	34.1	28.2	17
" , 3 m	60.9	64.6	75.5	72.5	93.3	73.4	17
^{137}Cs , 10 m	12.3	12.7	16.5	14.2	-	13.9	14
" , 5 m	50.8	52.4	38.5	65.1	-	51.7	21
" , 3 m	144.4	147.7	187.5	162.7	-	160.6	12

Table 5.2.4. GM counter results from measurements of calibration sources (μR h^{-1}).

Source, distance	Detector No. 19	20	21	22	23	Mean	1SD(%)
^{226}Ra , 10 m	10.0	1.0	10.8	1.0	6.9	5.9	80
" , 5 m	42.0	48.6	43.6	20.7	23.5	35.7	36
" , 3 m	97.0	119.6	122.6	68.2	70.1	95.5	27
^{137}Cs , 10 m	14.0	20.7	24.7	6.9	7.8	14.8	53
" , 5 m	55.0	88.3	96.2	36.7	42.3	63.7	42
" , 3 m	137.0	232.1	236.1	151.6	137.4	178.8	28

The results were compared with the calculated exposure rates described in section 4 (Table 4.1). Regression lines for each detector were fitted to the results from the ^{226}Ra source and to the results from the ^{137}Cs source, and the two lines were furthermore combined (See Table 5.2.5). Ideally the lines should be identical and the combined regression line should yield a value of unity for the slope α and zero for the intercept β.

Table 5.2.5. Relative γ-ray detector responses from measurements of two certified sources (^{226}Ra and ^{137}Cs) at three distances. The table shows coefficients, α and β, from regression lines, $y = \alpha x + \beta$, fitted to the data. The uncertainties are 95% confidence limits.

Detectors		^{226}Ra source* α	β	^{137}Cs source* α	β	Combined** α	β
	1	1.02 ± 0.11	-1 ± 6	0.98 ± 0.04	0 ± 5	0.99 ± 0.03	0 ± 2
	2	0.91 ± 0.13	1 ± 13	0.94 ± 0.23	1 ± 13	0.91 ± 0.03	2 ± 2
Ionization chambers	3	0.91 ± 0.09	-1 ± 5	0.92 ± 0.11	-1 ± 11	0.92 ± 0.02	-1 ± 2
	4	0.95 ± 0.10	1 ± 6	0.93 ± 0.19	0 ± 19	0.93 ± 0.03	1 ± 2
	5	0.99 ± 0.05	0 ± 5	1.01 ± 0.10	1 ± 6	1.00 ± 0.01	0 ± 1
	6	1.64 ± 0.29	3 ± 17	1.60 ± 0.81	6 ± 83	1.63 ± 0.11	1 ± 9
	7	1.32 ± 0.61	4 ± 35	1.17 ± 0.80	10 ± 82	1.20 ± 0.12	8 ± 10
	8	1.30 ± 0.68	2 ± 40	1.19 ± 0.42	7 ± 43	1.22 ± 0.08	6 ± 7
Plastic scintillators	9	1.11 ± 0.00	3 ± 0	1.13 ± 0.10	5 ± 10	1.14 ± 0.03	4 ± 3
	10	1.01 ± 0.33	4 ± 19	1.17 ± 0.22	-1 ± 22	1.14 ± 0.10	0 ± 8
	11	1.34 ± 0.28	1 ± 16	1.33 ± 0.37	1 ± 38	1.33 ± 0.04	1 ± 3
	12	1.19 ± 0.49	3 ± 28	1.42 ± 0.51	4 ± 52	1.41 ± 0.22	-1 ± 19
	13	0.92 ± 0.18	-1 ± 10	1.03 ± 0.24	3 ± 24	1.01 ± 0.08	-4 ± 6
	14	0.65 ± 0.20	0 ± 12	0.88 ± 0.17	-2 ± 18	0.86 ± 0.18	-5 ± 12
	15	0.70 ± 0.00	0 ± 0	0.90 ± 0.14	-2 ± 18	0.88 ± 0.16	-5 ± 14
NaI(Tl) scintillators	16	0.80 ± 0.61	2 ± 35	1.19 ± 2.81	-15 ±288	1.11 ± 0.34	-11 ± 28
	17	0.77 ± 0.26	1 ± 15	0.98 ± 0.52	1 ± 53	0.97 ± 0.19	-3 ± 16
	18	1.00 ± 0.04	0 ± 2				
	19	1.01 ± 0.92	4 ± 53	0.81 ± 0.32	3 ± 33	0.83 ± 0.19	7 ± 16
	20	1.37 ± 1.91	-6 ±110	1.40 ± 0.28	0 ± 29	1.42 ± 0.14	-5 ± 12
GM counters	21	1.32 ± 0.19	-1 ± 11	1.40 ± 0.65	6 ± 66	1.41 ± 0.15	0 ± 13
	22	0.80 ± 0.12	-6 ± 7	0.99 ± 1.34	-15 ±137	0.95 ± 0.16	-12 ± 14
	23	0.76 ± 0.42	-1 ± 24	0.87 ± 0.47	-8 ± 48	0.84 ± 0.08	-5 ± 7

* Uncertainties based upon a single degree of freedom each.
** Uncertainties based upon two degrees of freedom each.

In most cases the 95% confidence intervals for the β coefficients contain the value zero. However, the 95% confidence intervals for the slope α, do not generally include unity. This is depicted in Fig. 5.2.1 which shows the α coefficients with error-bars representing the confidence intervals.

From Fig. 5.2.1 is seen that, with respect to precision and accuracy, the ionization chamber results perform better than those from other detector types. The plastic scintillators seem to overestimate and the NaI scintillators to underestimate the results.

The results from the Ge(Li) detector measurements of the two calibration sources at 4 m distance are shown in Table 5.2.6 in terms of unattenuated γ-flux densities.

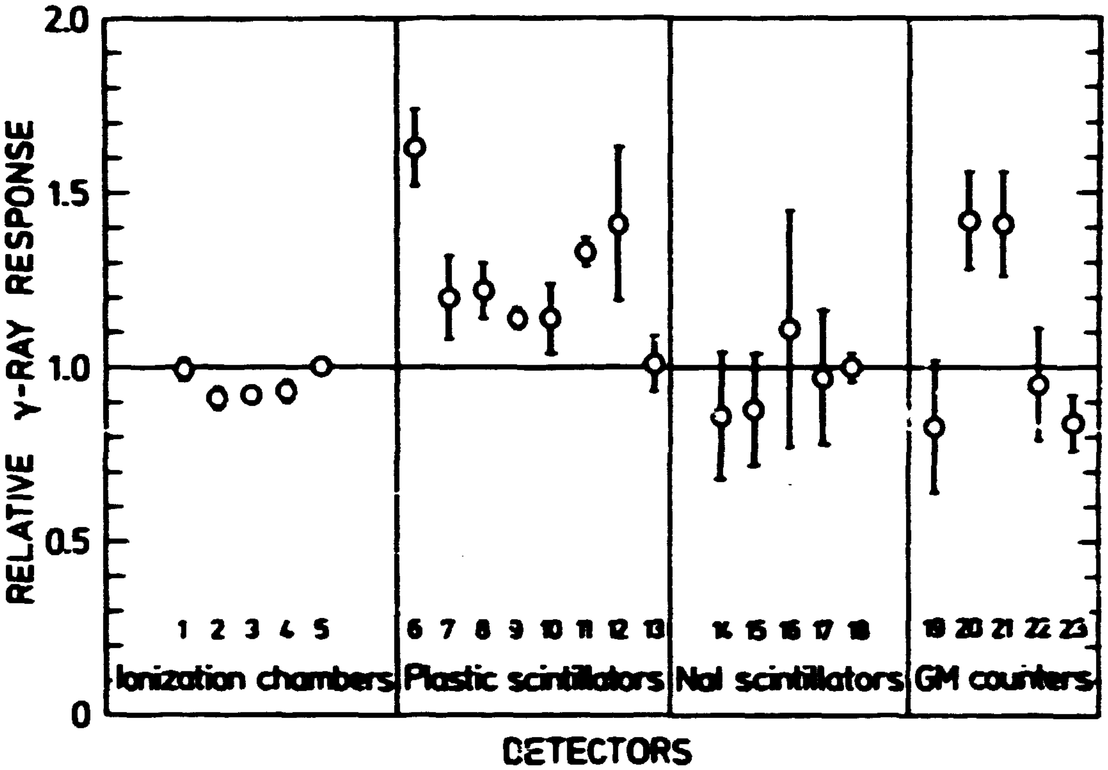

Fig. 5.2.1. Relative gamma-ray responses from measurements of certified sources (^{226}Ra and ^{137}Cs). The error bars represent 95% confidence intervals.

Table 5.2.6. Germanium detector results of unattenuated γ-flux density from measurements of calibration sources at 4 m distance ($\gamma\ cm^{-2}\ s^{-1}$).

Source, γ-energy	Detector No. 1	2	3
^{226}Ra , 295 keV	2.1	2.0	2.2
" , 352 keV	4.5	4.3	4.6
" , 609 keV	6.7	6.3	6.6
" , 1120 keV	2.4	2.4	2.4
" , 1765 keV	2.4	2.5	2.5
^{137}Cs , 662 keV	63	56	61

5.3. TLD measurements.

A total of 10 sets of TL dosimeters were exposed in the Risø irradiation facility to 48 mR and 18 mR ^{60}Co radiation and to 38 mR and 14 mR ^{137}Cs radiation. The results of the exposures reported by the participants are given in Table 5.3.1 and in Fig. 5.3.1.

To facilitate a common analysis of all the TL results, they were normalized relative to the estimated laboratory exposures and used in a three-way analysis of variance. The three parameters to be investigated were dosimeter type, dose level and γ-source. The analysis was performed without the results from TLD set no. 18, since these are obvious outlyers. The result of the analysis is shown in Table 5.3.2, where SSD denotes the sum of squares of deviations, df the number of degrees of freedom, s^2 the variance estimate and v^2 the observed variance ratio. The average ratio between the reported exposures and the estimated laboratory exposures was 0.96. It is noted that the first-order interaction between dosimeter types and dose levels is probably significant, which means that the different dosimeter types do not show identical variations with dose levels (e.g. problems

Table 5.3.1. TLD results from measurements of laboratory exposures (mR).

TLD No.	^{60}Co high	^{60}Co low	^{137}Cs high	^{137}Cs low
1	47.0	18.9	39.4	14.4
2	41.0	16.0	35.0	14.0
3	44.0	17.0	35.0	14.0
4	45.0	17.0	36.0	13.0
5	49.0	19.0	44.0	14.0
6	37.0	16.0	32.0	13.0
7	36.8	18.2	32.9	16.0
8	60.0	23.0	45.0	19.0
9	45.0	17.1	38.0	14.4
10	45.8	16.8	38.5	14.3
Mean	45.1	17.9	37.6	14.6
1SD(%)	14.7	11.6	11.6	12.0
Estimated lab. exposure	48.0	18.0	38.0	14.0

connected with correction for background). Neither the variation between different dosimeter types nor that between different dose level is significant. Tendencies of significant variations due to these parameters were masked since the variances were tested against the probably significant first-order interaction. The variation between γ-sources was highly significant following the pattern that the dosimeters tend to yield a higher response to ^{137}Cs-radiation than to ^{60}Co-radiation.

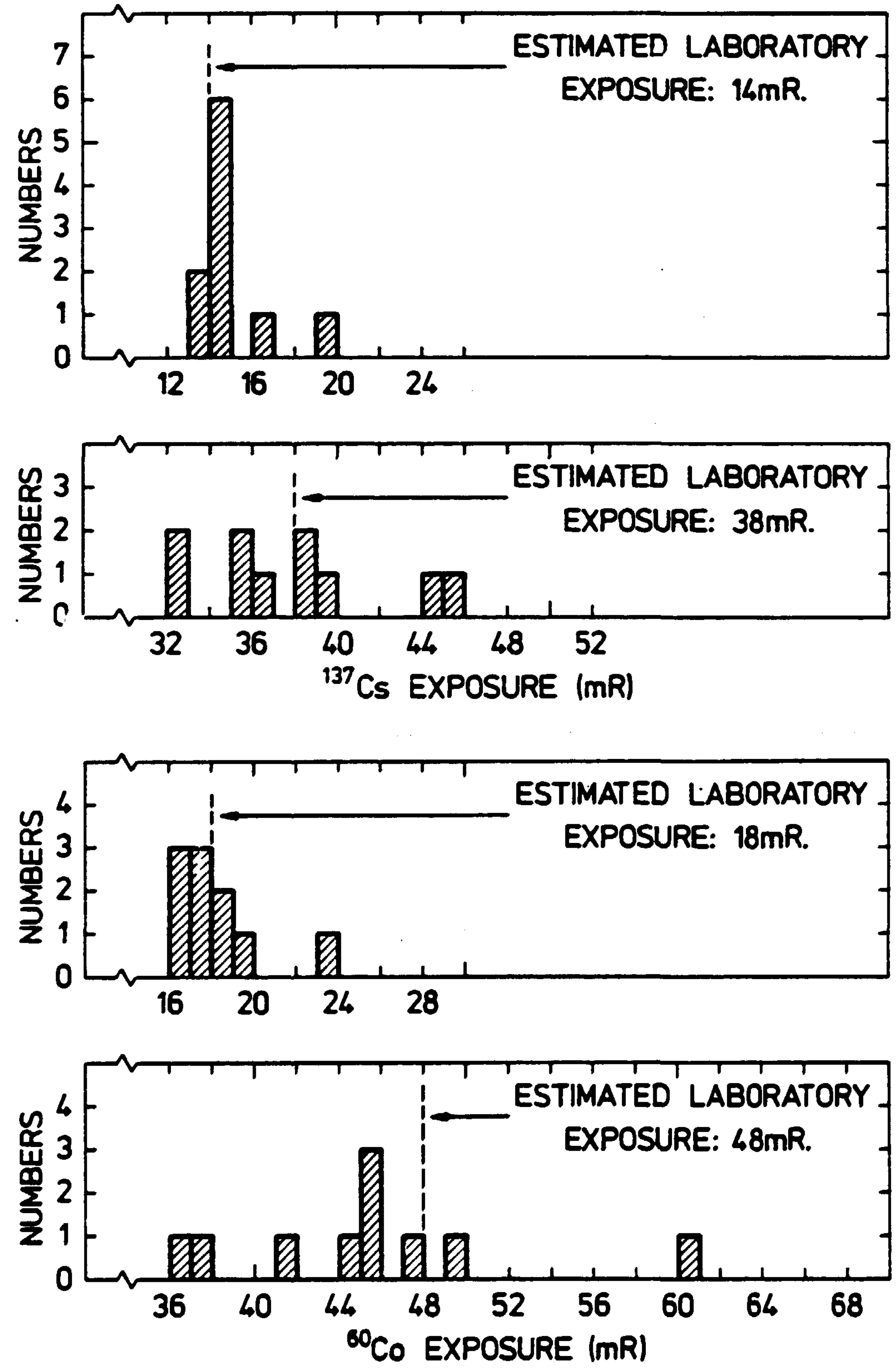

Fig. 5.3.1. Results from TL dosimeters irradiated at Risø and evaluated at different Scandinavian laboratories.

Table 5.3.2. Analysis of variance of all TLD-results except for one set, normalized to estimated laboratory exposures.

Nature of effect	Source	SSD	df	s^2	v^2	Significance
Main factors	dosimeter (D)	0.118	8	0.015	1.76	NS
	dose level (L)	0.024	1	0.024	2.89	NS
	γ-source (S)	0.026	1	0.026	17.93	P>99.9%
First-order interaction	D x L	0.067	8	0.008	5.41	P>95%
	L x S	0.001	1	0.001	0.49	NS
	D x S	0.012	8	0.001	0.93	NS
Second-order interaction	D x L x S	0.012	8	0.002	0.07	NS

NS not significant

6. CONCLUSION

Several Nordic laboratories participated in an intercalibration programme with different types of instruments and detectors. Ionization chambers appeared to yield the most reliable results but in general large variations of detector responses were found when the instruments were exposed identically. This demonstrates the need for intercomparison programmes and for establishing standardized calibration procedures.

Environmental monitoring of the background radiation is important and urgently needed to meet regulatory requirements. It is necessary to continue research within this field to improve present procedures and to develop easy and reliable measuring techniques for the control of radiation doses to humans from the environment.

Intercomparison programmes play an important role in establishing homogenous measuring and dosimetry practices; thus a continuation of such programmes is of great value for further improvements and refinements.

A vital factor of intercomparison programmes is the subsequent information and discussion of the results. Therefore meetings, such as the present one are of considerable value to the participants in assessing the state of the art in relation to practices operating in the respective laboratories.

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A nordic intercomparison of detector systems for background radiation monitoring Lars Bøtter-Jensen and Sven Poul Nielsen	Department or group Health Physics Dept.
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Abstract

A Nordic meeting sponsored by the Nordic Liaison Committee for Atomic Energy, was held at Risø 2-4 June 1980 with the aim of intercomparing detector systems for background radiation monitoring.

Several Nordic Laboratories participated in the intercalibration programme with different types of instruments and detectors. Ionization chambers appeared to yield the most reliable results but in general large variations of detector responses were found when the instruments were exposed identically. This demonstrates the need for intercomparison programmes and for establishing standardized calibration procedures.

The present paper gives a description of the programme and presents the results for the assessment of background radiation monitoring with different sensitive doserate meters and integrating Tl dosimeters.

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